The effect of cold upon the aqueous acid was briefly examined, the result being that a comparatively small amount of hydrofluoric acid lowers the freezing-point of water very considerably.

The chemico-electric series of metals &c. in acid of 10 per cent. and in that of 30 per cent. were determined. In the latter case it was as follows :—zinc, magnesium, aluminium, thallium, indium, cadmium, tin, lead, silicon, iron, nickel, cobalt, antimony, bismuth, mercury, silver, copper, arsenic, osmium, ruthenium, gas-carbon, platinum, rhodium, palladium, tellurium, osmi-iridium, gold, iridium. Magnesium was remarkably unacted upon in the aqueous acid. The chemico-electric relation of the aqueous acid to other acids with platinum was also determined.

Various experiments of electrolysis of the aqueous acid of various degrees of strength were made with anodes of platinum. Ozone was evolved, and, with the stronger acid only, the anode was corroded at the same time. Mixtures of the aqueous acid with nitric, hydrochloric, sulphuric, selenious, and phosphoric acids were also electrolyzed with a platinum anode, and the results are described.
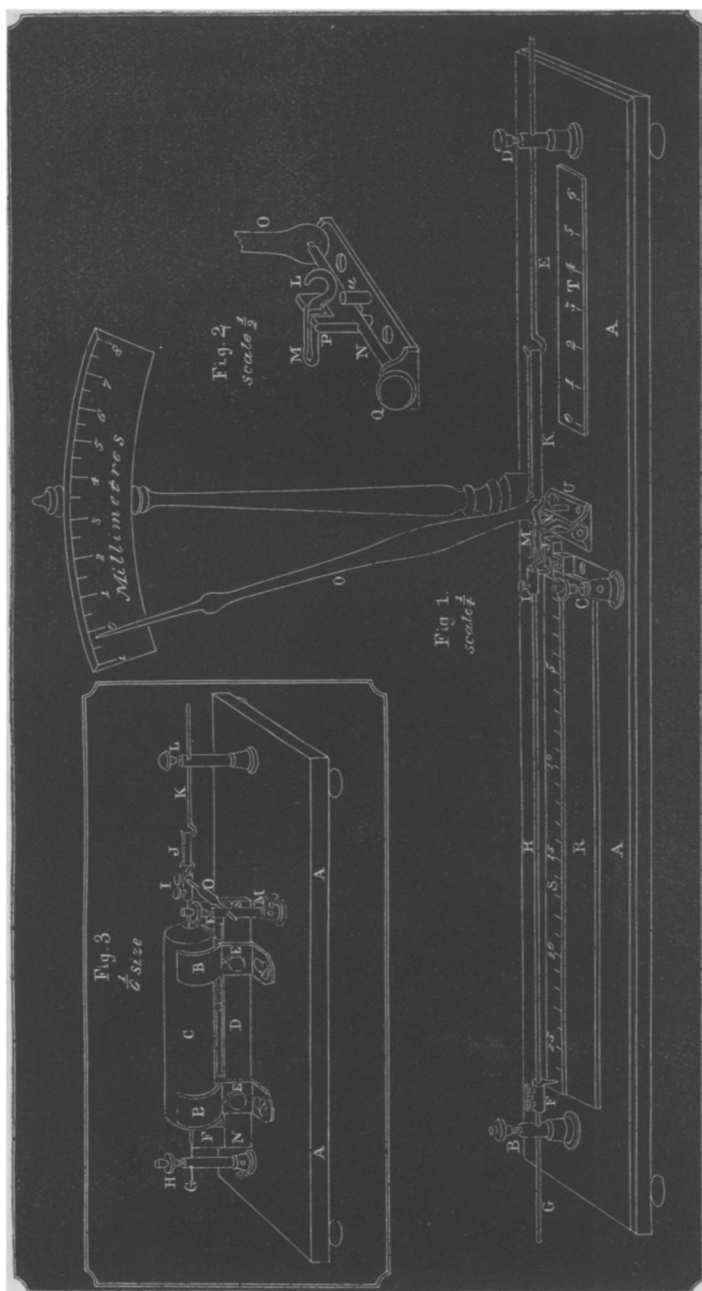

III. " On a momentary Molecular Change in Iron Wire."
   By G. Gore, F.R.S.   Received November 14, 1868.

Whilst making some experiments of heating a strained iron wire to redness by means of a current of voltaic electricity, I observed that, on disconnecting the battery and allowing the wire to cool, during the process of cooling the wire *suddenly elongated,* and then gradually shortened until it became quite cold.

On attempting, some little time afterwards, to repeat this experiment, although a careful record of the conditions of the experiment had been kept, it was with some difficulty, and after numerous trials, that I succeeded in obtaining the same result. Having again obtained it, I next examined and determined the successful conditions of the experiment, and devised the following arrangement of apparatus.

A A (fig. 1) is a wooden base 61 centimetres long and 15·5 centimetres wide. B and C are binding-screws ; they are provided with small brass mercury-cups fixed in the heads of the screws for attachment of the wires of a voltaic battery. D is a binding-screw for holding fast the sliding wire hook E. F is a cylindrical binding-screw, fixed to the sliding wire G, which is held fast by the binding-screw B. H is the iron or other wire (or ribbon) to be heated : one end of this wire passes through the screw F and is tightly secured by it, whilst the other end is held fast by the cylindrical binding-screw I ; the binding-screw I has a small projecting bent piece of copper wire secured to it, which dips into a little shallow dish or cup of mercury, J ; and the mercury in this cup is connected by a screw and strip of brass to the binding-screw C. K is a stretched band of vulcanized india-rubber, attached at one end to the hook of the wire E, and

Fig. 1 scale ¼

Fig. 2 scale ½

Fig. 3 ⅙ size

Millimetres

at the other end to the hook L (see fig. 2). The cylindrical binding-screw I has a hook by which it is attached to the loop M (fig. 2). N is an axis suspended delicately upon centres, and carrying a very light index pointer O. The hook L and loop M are separate pieces of metal, and move freely upon an axis, P (fig. 2). The distance from the centre of the axis N to that of P is 12·72 millimetres (=0·5 inch), and to the top of the index pointer 25·45 centimetres (=10·0 inches); every movement horizontally, therefore, of the loop M is attended by a movement, twenty times the amount, of the top of the pointer. Q is a screw for supporting the axis N. I have found it convenient to put the zero-figure of the index towards the left-hand side of the index-plate. R is a separate piece of wood fitting into a rectangular hole in the base board; it carries a graduated rule, S, for measuring the length of the wire to be heated, and is easily removed, so that the wire may, if necessary, be heated by means of a row of Bunsen's burners. The rule T is used when measuring the amount of strain. U is a vertical stud or pin of brass (of which there are two) for limiting the range of movement of the pointer O.

In using this apparatus, a straight wire or ribbon, H, of a suitable length and thickness was inserted, the index pointer brought to 0 by adjustment of the sliding-wire G, and a suitable amount of strain (varying from less than two ounces to upwards of twenty) put upon the wire by adjusting the sliding hooked wire E. One pole of a voltaic battery, generally consisting of six Grove's elements, was connected with the binding-screw C, and the other pole then inserted in the mercury-cup of B. As soon as the needle O attained a maximum or stationary amount of deflection, the battery-wire was suddenly removed from B, and the wire allowed to cool. The movement of the needle O was carefully watched both during its movement to the right hand and also during its return, to see if any irregularity of motion occurred.

Wires of the following metals and alloys were employed :—palladium, platinum, gold, silver, copper, iron, lead, tin, cadmium, zinc, brass, german-silver, aluminium, and magnesium; metallic ribbon was also employed in certain cases.

In these experiments the thickness and length of the conducting-wire or ribbon had to be carefully proportioned to the quantity and electromotive power of the current, so as to produce in the first experiments with each metal only a very moderate amount of heat; thinner (and sometimes also shorter) wires were then successively used, so as ultimately to develope sufficient heat to make the metal closely approach its softening or fusion-point. The battery employed consisted in each case of six Grove's cells, each cell containing two zinc plates $3\frac{3}{4}$ inches wide, and a platinum plate 3 inches wide, each immersed about 5 inches in their respective liquids. The amount of tension imparted by the elastic band required to be carefully adjusted to the cohesive power of each metal; if the stretching power was too weak, the phenomenon sought for was not clearly deve-

loped; and if too great, the wire was overstretched or broken when it approached the softening-point. The amount of strain imparted was approximately measured by temporarily substituting the body of a small spring balance for the hooked wire F. The heated wire must be protected from currents of cold air.

With wires of iron 0·65 millimetre thick (size " No. 23") and 21·5 centimetres long, strained to the extent of 10 ounces or more, and heated to full redness, the phenomenon was clearly developed. As an example, the needle of the instrument went with regularity to 18·5 of index-plate; the current was then stopped; the needle instantly retreated to 17·75, then as quickly advanced to 19·75, and then went slowly and regularly back, but not to zero. If the temperature of the wire was not sufficiently high, or the strain upon the wire not enough, the needle went directly back without exhibiting the momentary forward movement. The temperature and strain required to be sufficient to actually stretch the wire somewhat at the higher temperature. A higher temperature with a less degree of strain, or a greater degree of strain with a somewhat lower temperature, did not develope the phenomenon. The wire was found to be permanently elongated on cooling. The amount of elongation of the wire during the momentary molecular change was usually about $\frac{1}{240}$ part of the length of the heated part of the wire; but it varied in different experiments; it was greatest in amount when the maximum degrees of strain were applied. The molecular change evidently includes a diminution of cohesion at a particular temperature during the process of cooling; and it is interesting to notice that at the same temperature during the *heating*-process no such loss of cohesion (nor any increase of cohesion) takes place; a certain temperature and strain are therefore not alone sufficient to produce it; the condition of *cooling* must also be included. The phenomena which occur during cooling are not the exact converse of those which take place during heating.

The phenomenon of elongation of iron wire during the process of cooling evidently lies within very narrow limits; it could only be obtained (with the particular battery employed) with wires about 21·5 centimetres ($=8\frac{7}{16}$ inch) long, and about 0·65 millimetre ($=$Nos. 22 & 23 of ordinary wire-gauge) thick, having a strain upon them of 10 ounces or upwards; with a weaker battery the phenomenon could only be obtained by employing a shorter and thinner wire.

The experiment may easily be verified in a simpler manner by stretching an iron wire about 1·0 millimetre diameter between two fixed supports, keeping it in a sufficient and proper degree of tension by means of an elastic band, then heating it to full redness by means of a row of Bunsen's burners, and, as soon as it has stretched somewhat, suddenly cutting off the source of heat. In some experiments of this kind, with a row (42 centimetres long) of 21 burners and a row (76 centimetres long) of 43 burners, and the wire attached to a needle with index-plate, as in the figure, conspicuous effects were obtained; but the momentary elongation was relatively

much less (in one instance $\frac{1}{800}$ of the length of the heated part) than when a battery was employed, apparently in consequence of the wire being less intensely heated.

A large number of experiments were made with wires of palladium, platinum, gold, silver, copper, lead, tin, cadmium, zinc, brass, german-silver, aluminium, and magnesium (wire and ribbon), diminishing the length and thickness of the wire in each case, and adjusting the tension until suitable temperature and strain were obtained; but in no instance could a similar molecular change to that observed in iron be detected. Palladium and platinum wires of different lengths, thickness, and degrees of strain were examined at various temperatures, up to that of a white heat; but no irregularity of cohesion, except that of gradual softening at the higher temperatures, was observed; they instantly contracted with regular action on stopping the current. Several gold wires were similarly examined at different temperatures up to that of a full red heat; no irregularity occurred either during heating or cooling; but little tension (about 4 ounces) was applied, on account of the weak cohesion of this metal. Wires of silver similarly examined would only bear a strain of about 2 ounces, and a temperature of feeble red heat visible in daylight; no irregularity of elongation or contraction occurred during heating and cooling. By employing exactly the proper temperature and strain, a very interesting phenomenon was observed; the wire melted distinctly *on its surface* without fusing in its interior, although the surface was most exposed to the cooling influence of the air; this occurred without the wire breaking, as it would have done if its interior portion had melted; the phenomenon indicates the passage of the electricity by the *surface* of the wire in preference to passing by its interior. Wires of copper expanded regularly until they became red-hot; they then contracted slightly (notwithstanding the strain applied to them), probably in consequence of a cooling effect of increased radiation produced by the oxidized surface, as a similar effect occurred with brass and german-silver*. On stopping the current the wire contracted without manifest irregularity. Wires of lead and tin were difficult to examine by this method, on account of their extremely feeble cohesion and the low temperature at which they softened: wires about 1·63 millimetre diameter, 25·5 centimetres long (with a strain upon them of about one ounce), were employed; no irregularity was detected. Wires of cadmium from 1·255 millimetre to 1·525 millimetre thick, and 24·2 centimetres long (with a strain of two ounces), exhibited a slight irregularity of expansion at the lower temperatures; they elongated, and also cooled, with extreme slowness, more slowly than those of any other metal. Wires of zinc exhibited a slight irregularity of expansion, like those of cadmium; the most suitable ones were about 25 centimetres long and 1·2 millimetre in diameter, with a strain of 10 ounces. Wires of brass and german-silver, when heated to redness,

* This supposition does not agree with the results obtained with iron wire, which also oxidizes freely.

behaved like those of copper in expanding regularly until a maximum was attained, and then contracting slightly to a definite point whilst the battery remained connected ; on stopping the current they contracted without irregularity. When examined at lower temperatures, with a greater degree of strain, no irregularity was observed. Various wires of aluminium were examined ; the most suitable was one 0·88 millimetre thick, 20·4 centimetres long, with a strain of 12 ounces'; no irregularity was observed at any temperature below redness ; aluminium expanded and cooled very slowly, but less so than cadmium. Various wires and ribbon of magnesium were also examined below a red heat, but no irregularity of cohesion, except that due to gradual softening by heat, was detected.

All the metals examined exhibited gradual loss of cohesion at the higher temperatures if a suitable strain was applied to develope it. It is probable that if the fractions of time occupied by the needle in passing over each division of the index were noted, and the wire perfectly protected *from* currents of air, small irregularities of molecular or cohesive change might be detected by this method ; cadmium and zinc offer a prospect of this kind.

This molecular change would probably be found to exist in large masses of wrought iron as well as in the small specimens of wire which I have examined, and would come into operation in various cases where those masses are subjected to the conjoint influence of heat and strain, as in various engineering operations, the destruction of buildings by fire, and other cases.

IV. " On the Development of Electric Currents by Magnetism and Heat." By G. GORE, F.R.S. Received November 14, 1868.

I have devised the following apparatus for demonstrating a relation of current electricity to magnetism and heat.

A A, fig. 3, is a wooden base, upon which is supported, by four brass clamps, two, B, B, on each side, a coil of wire, C ; the coil is 6 inches long, $1\frac{1}{2}$ inch external diameter, and $\frac{3}{8}$ of an inch internal diameter, lined with a thin glass tube ; it consists of 18 layers, or about 3000 turns of insulated copper wire of 0·415 millim. diameter (or size No. 26 of ordinary wire-gauge) ; D is a permanent bar-magnet held in its place by the screws E, E, and having upon its poles two flat armatures of soft iron, F, F, placed edgewise. Within the axis of the coil is a straight wire of soft iron, G, one end of which is held fast by the pillar-screw H, and the other by the cylindrical binding-screw I ; the latter screw has a hook, to which is attached a vulcanized india-rubber band, J, which is stretched and held secure by the hooked brass rod K and the pillar-screw L. The screw H is surmounted by a small mercury cup for making connexions with one pole of a voltaic battery, the other pole of the battery being secured to the pillar-screw M,